Ricos Biology Journal, May, 2025, Vol. 3 (5) 62-73. www.ricosbiology.net/Vol.3(5)/May-2025/62

GENETIC EVALUATION OF YIELD-RELATED AGRONOMIC TRAITS FROM HALF-SIB FAMILIES OF MAIZE (*ZEA MAYS* L.)

Nasr Ullah Khan[1*], Muhammad Ishfaq Khan[2], Rida Nisar[3], Muhammad Muddasir[1], Muhammad Umer Mustafa[1], Abdul Majid[4], Muhammad Saad Ahmed[5], Muhammad Arshad[6], Rehan Naeem[7], Mohsin Khurshid[8], Muhammad Khuram Razzaq[9]

[1]Department of Plant Breeding & Genetics, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan.
[2]Department of Botany, University of Science and Technology Bannu, Khyber Pakhtunkhwa, Pakistan.
[3]Department of Horticulture, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan.
[4]Department of Agricultural Chemistry & Biochemistry, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan.
[5]Department of Biological Sciences, National University of Medical Sciences, Rawalpindi, Pakistan.
[6]Department of Biosciences, International Islamic University Islamabad, Islamabad, Pakistan.
[7]Department of Biotechnology and Genetic Engineering, Kohat University of Science & Technology, Kohat, Pakistan.
[8]Department of Microbiology, Government, College University Faisalabad, Pakistan.
[9]Soybean Research Institute, National Center for Soybean Improvement, Nanjing Agricultural University, Nanjing, China.

*Corresponding Author: **Nasr Ullah Khan** Email: nasrkhanpbg@gu.edu.pk

Received: 11-05-2025 **Accepted:** 20-05-2025 **Published online:** 24-05-2025

DOI: https://doi.org/10.33687/ricosbiol.03.05.62

Abstract

This study was conducted to evaluate half-sib families (HSF) for yield and agronomic traits in maize (*Zea mays* L.). One hundred and ninety-six half-sib families were used in this study derived from the maize variety Azam. The experiment was laid out in 14×14 partial lattice square designs with two replications. Results indicated that the phenotypic coefficient of variance was higher than the genotypic coefficient of variance for all traits except for fresh ear weight, which reflects the environmental influence on the expression of the trait. High to moderate heritability was observed for days to tasseling, days to mid silking, days to anthesis, anthesis silking-interval, kernel rows per cob, cob length, and grain yield. Highly significant and positive correlations were observed between grain yield and cob length (0.99), kernel rows per cob (0.88), grain moisture (1.00), days to tasseling (0.94), silking (0.99), and anthesis (0.96). The negative and non-significant correlation was observed between grain yield and fresh ear weight (-0.06). Maximum grain yields of 10710 kg ha^{-1} were recorded for HSF-180, while a minimum 2046 kg ha^{-1} was obtained by HSF-31. These results suggest that these half-sib families could be used as a source of maize germplasm for developing maize genotypes with superior attributes.

Keywords: Half-sib Families, Replication, Yield Attributes, Zea mays L.

Introduction

Global production of all cereal crops is not adequate to nourish the whole population, although the crops yield is increasing day-by-day (STAT, 2012). According to the FAO data,

Ricos Biology Journal, May, 2025, Vol. 3 (5) 62-73. www.ricosbiology.net/Vol.3(5)/May-2025/62

in 2010 the coarse crop-producing countries that contribute greater than 20% of total production are the United States of America and China (STAT, 2012). Maize (*Zea mays* L.) is the world's primary coarse grain that plays a vital role as the source of bioenergy, animal feed, and human food (Zhou et al., 2012). It is the world's foremost cereal crop a production of 695 million tons and a per-unit area yield of 4815 kg, ha^{-1} and a vast quantity of production is concentrated in the United States of America. The top five maize producing countries are the USA, China, Brazil, Mexico and Argentina have drastically increased the maize production since 1961 (STAT, 2012). It is the prime crop of Sub-Saharan Africa, accounting 51% of consumed calories although the yield level is low and vehemently variable across years at less than 2 t/ha. On the other hand, in Asia, the yield level is much higher. China and Indonesia accounting an average yield of 5.2 and 4.2 t/ha (STAT, 2012).

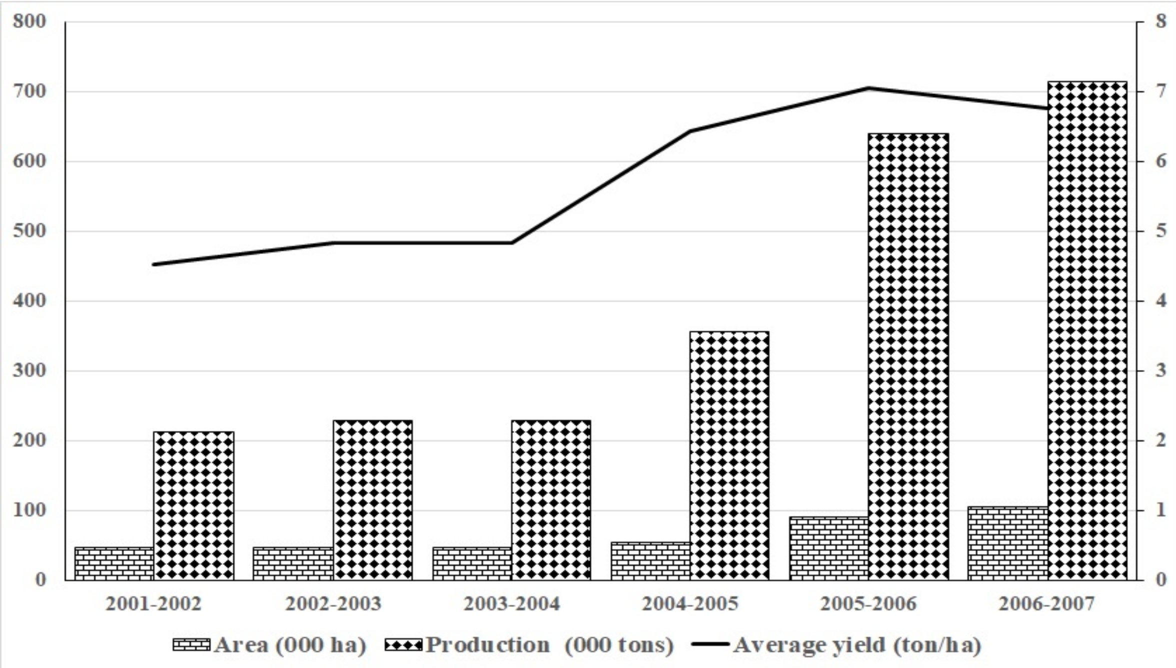

Fig. 1 Area (000 ha), Production (000 tons), and average yield (ton/ha) of spring maize in Pakistan

Pakistan contributes a production of 3.3 million tons per year with an estimated planted area of 1.016 million hectares and an average yield of 2864 $kgha^{-1}$ (Tariq and Iqbal, 2010). In Pakistan, production per year increases with a decrease in the cultivated areas (STAT, 2012). The production of maize has increased drastically over the decades from 0.38 to 3.037 million tons during 1947-2007 (Tariq and Iqbal, 2010). The area, production, and average yield of spring maize from 2001 to 2007 increased drastically (Figure 1). 99 % of the total production of maize comes from the Khyber Pakhtunkhwa and Punjab provinces of Pakistan. Khyber Pakhtunkhwa accounts for 31 % of the total maize production and 51 % of the total area (Tariq and Iqbal, 2010). In Khyber Pakhtunkhwa, maize is normally grown to produce grain and also as fodder, due to which its demand increased drastically. In combination with the Green Revolution, improved agronomic practices enhanced yields up to 40% (Evenson and Gollin, 2003). Maize improvement mainly includes evaluation, selection, and recombination of genetically distinct inbred lines or families (Pixley et al., 2006).

A number of recurrent selection methods have been used by the breeders, like mass selection, recurrent selection, half-sib selection, and full-sib family selection, for developing high-yielding maize varieties and increasing yield per unit area (Keeratinijakal and Lamkey, 1993). Recurrent selection methods comprising half-sib family selection and S_1 progeny selection are particularly of prime interest as these not only improve the breeding population for the required attributes but also sustain the genetic variability in the population (Hallauer, 2012). Coors (1988) observed a 1.5% reduction in grain moisture and a gain of 3.5% in grain yield per cycle in response to four cycles of combined half-sib and S_1 family selection in maize. Tanner and Smith (1987) recommended that half-sib family selection was highly efficient in reducing inbreeding depression in maize populations. Marquez-Sanchez (2003) evaluated different selection methods for maize and based on their results recommended that HS-selection is the best method.

The present research was designed with the objectives to evaluate half-sib families developed from maize variety Azam and to identify superior half-sib families for yield and agronomic traits that can be used in future maize breeding programs for developing maize genotypes with desirable attributes.

Materials and methods

Experimental material of the study comprised 196 half-sib family lines–having one parent in common-derived from maize variety Azam, which were provided by the Cereal Crops Research Institute (CCRI), Pirsabak, Nowshera, Pakistan. A partial lattice square design, having two replications, was used. Plant-to-plant and row-to-row distance was 25 cm and 75 cm, respectively. The land was prepared by giving three plowings followed by planking. Standard cultural practices, including irrigation, fertilizer application, and hoeing, were carried out over the growing season. Agronomic practices were carried out at the proper time. Data on yield and morphological parameters were recorded at the proper time for each character.

Silking data were recorded on a plant basis as the number of days from silking till 50% of plants in the plot showed silks, while days to anthesis were worked out by visual observation when 50% of the plants in the plot started pollen shedding. From the date of sowing, days were counted. Anthesis silking interval (ASI) was computed on a plot basis as the difference between silking and anthesis. Plant height using a graduated meter rod in cm was computed from the ground level to the topmost node of the plant, and an average of five randomly selected plants per row was taken, whereas ear height was also computed in cm as an average of five randomly selected plants per row from ground level to the node bearing the uppermost ear. Ear length was computed as an average of three per row from the tip to the base of the ear with the scale in cm, whereas kernel rows per ear were counted on the three randomly selected ears after harvesting. The moisture content of the grains was taken using a grain moisture tester after shelling the middle rows from three randomly selected ears per row at harvesting time. A hundred kernels were counted randomly from the grain lot of each row and weighed with the help of an electronic balance. Total grain yield per hectare was calculated from the data of fresh ear weight using formula:

$$\text{Grain Yield (kg ha}^{-1}\text{)} = \frac{(\text{F.wt (kg)} \times 100\text{-M.C}) \times 0.8 \times 10{,}000}{(100\text{-}15) \times \text{harvesting area}}$$

Whereas MC = moisture content (%) in grains at harvest, 0.8 = Shelling co-efficient, 15% = moisture content required in grain at storage

The data of agronomic traits were analyzed using PROC MIXED procedure to determine the relationship among the traits; phenotypic correlation coefficients were computed among all the traits. Variance components were estimated to know the environmental and genetic effects on different characters. Phenotypic (δ^2_P), genotypic (δ^2_G) and error (δ^2_E) variances were computed from mean squares of analysis of variance by using the formula suggested by Hallauer et al. (2010). The standard errors of estimates of genotypic and error variance components were computed using the methods of Hallauer et al. (2010). The genetic advance (GA) was calculated as devised by Johnson (1955). The following formulas were used are;

Error Variance, $\delta^2_E = MS_E$, where MS_E = mean square of error

Genotypic variance, $\delta^2_G = (MS_G - MS_E)/r$, where MS_G = mean square of genotype, MS_E = mean square of error, and r = number of replications

Phenotypic variance, $\delta^2_P = \delta^2_E + \delta^2_G$, where δ^2_E = error variance and δ^2_G = genotypic variance

Genotypic coefficient of variation, GCV= $\left(\frac{\sqrt{\delta^2_G}}{X}\right)\times 100$, where δ^2_G = genotypic variance and X = mean of the trait

Phenotypic coefficient of variation, PCV = $\left(\frac{\sqrt{\delta^2_P}}{X}\right)\times 100$, where δ^2_P = phenotypic variance and X = mean of the trait

Heritability $h^2 = \delta^2_G / \delta^2_P$, where δ^2_G = genotypic variance and δ^2_P = phenotypic variance

Genetic Advance GA = $k \sqrt{\delta^2_P} . h^2$, where $\sqrt{\delta^2_P}$ = Square root of Phenotypic Variance, h^2 = Heritability, and K= Constant, 2.063 at 5% selection intensity

Results and discussion

This research was conducted at (34° 0' 29" N / 71° 34' 22" E), Peshawar, Pakistan which, under Koppen's climate classification, features a semi-arid climate with very hot summers and mild winters.

Days to 50% tasseling

The analysis of variance was taken for days to 50% tasselling and observed highly significant differences at P<0.01 for half-sib families. For days to tasselling a minimum mean value of 54 was observed for HSF-13, HSF-63, HSF-163, and HSF-189, while the maximum mean value of 60 was observed for HSF-114. The grand mean of 56.14 was observed for all 196 entries (Tab. 1). These results are in agreement with those observed by Hidayat et al. (2006), who also reported a highly significant difference for days to 50% tasselling when evaluating the performance of local and exotic inbred lines of maize under agro-ecological conditions of

Peshawar. The genotypic coefficient of variance was at the very low side as it was 0.03 % (Tab. 2).

Days to 50% Silking

Analysis of variance for days to 50% showed a significant difference among the half-sib families at P<0.05. For days to 50% silking minimum mean value of 57 was observed for HSF-13, HSF-116, HSF-66, and HSF-183, while the maximum mean value of 64.5 was observed in HSF-92, with a grand mean of 60.10 computed for all 196 entries (Tab. 1). The results of Hidayat et al. (2006) are also in comparison to our results. Because he also reported a highly significant difference for days to 50% silking when evaluating the performance of local and exotic inbred lines of maize under agro-ecological conditions of Peshawar. Similar results were also observed while working on "recurrent selection for grain yield in two Spanish maize synthetic populations". The genotypic coefficient of variance computed was 0.03 (Tab. 2).

Days to 50% Anthesis

Analysis of variance regarding days to 50% anthesis showed no significant difference among the half-sib families. The minimum value for days to 50% anthesis was observed as 54.5 days for HSF-13, while the maximum of 61.5 days was observed for HSF-114, having a grand mean of 57.52 days among 196 half-sib families (Tab. 1, Tab. 6). The coefficient of variance was very low, as it was recorded as 0.02 % (Tab. 2).

Anthesis Silking Interval (ASI)

ANOVA regarding anthesis silking interval showed a significant difference (P<0.05) with the genotypic coefficient of variance as 0.52 % (Tab. 2). ASI calculated ranged from 0.5 days for HSF-102, HSF-191, HSF-194, and HSF-16 (protogynous), while a maximum of 6.5 days was calculated for HSF-24 (protandrous), having a grand mean of 2.59 days among half-sib families (Tab. 1, Tab. 6). Rahman et al. (2010) observed similar results for anthesis-silking interval in test cross-evaluation of maize synthetic "BSSS" lines.

Plant Height

Plant height requires special attention from plant breeders as it plays an important role in plant lodging. Plants having an optimum height and central or near-to- central placement of cobs are more resistant to lodging and therefore play a vital role in improving grain yield. Highly significant differences (P<0.01) were recorded for plant height among the half-sib families. The genotypic coefficient of variance 0.09 was recorded, which was very low (Tab. 2). The average plant height ranged from 130 cm for HSF-120 and HSF-159 to 186 cm for HSF-56, with a grand mean of 154.1 cm (Tab. 1). Stromberg and Compton (1989) reported significant differences regarding plant height after 10 cycles of the full-sib recurrent section in Nebraska Krung open-pollinated maize.

Ear Height

ANOVA for ear height revealed highly significant differences (P<0.01) among 196 half-sib families. The genotypic coefficient of variance was 0.13 % (Tab. 2). Minimum mean ear height of 54cm was observed for HSF-156, while the maximum ear height 91 was recorded for HSF-56, with a grand mean of 71.98 for all 196 half-sib families (Tab. 1). Stromberg and Compton (1989) reported significant differences regarding ear height after 10 cycles of full-sib recurrent selection in an open-pollinated maize population.

Ricos Biology Journal, May, 2025, Vol. 3 (5) 62-73. www.ricosbiology.net/Vol.3(5)/May-2025/62

Table 1: General Statistics for the yield related agronomic traits.

	DT	DS	DA	ASI	PH (cm)	EH (cm)	CR	FEW	GMC	KR	CL	100-KW (g)	GY (kg ha^{-1})
Grand mean	56.14	60.10	57.52	2.59	154.11	71.98	8.67	0.98	23.44	13.35	14.81	32.27	4367.54
Maximum	60.00	64.50	61.50	6.50	186.0	91.00	14.50	2.15	30.75	16.84	19.17	41.00	10710.50
Minimum	54.00	57.00	54.50	0.50	130.0	54.00	3.00	0.30	14.95	11.00	9.34	20.00	2046.50
Standard Deviation	1.16	1.61	1.27	1.22	11.76	7.85	2.04	0.35	2.87	0.98	1.74	3.39	1180.95
Standard Error	0.08	0.12	0.09	0.09	0.84	0.56	0.15	0.02	0.21	0.07	0.12	0.24	84.35

Days To Tasseling (DT), Days to Silking (DS), Days to Anthesis (DA), Anthesis Silking Interval (ASI), Plant Height (PH), Ear Height (EH), Cobs Per Row (CR), Fresh Ear Weight (FEW), Grain Moisture Content (GMC), Kernal Rows Per Cob (KR), Cob Length (CL), 100-Kernal Weight (100-KW), Grain Yield (GY)

Table 2: Components of variance for the agronomic traits in Half-Sib Families of maize.

Parameters	(δ^2_G)	(δ^2_P)	(δ^2_E)	GCV%	PCV%
Days to Tasseling	2.36	2.71	0.35	0.03	0.03
Days to Silking	3.43	5.20	1.77	0.03	0.09
Days to Anthesis	1.84	3.22	1.38	0.02	0.06
Anthesis Silking Interval (ASI)	1.84	2.96	1.13	0.52	1.14
No of Plants/Row	6.79	11.07	4.28	0.24	1.01
Plant Height	183.87	276.73	92.86	0.09	1.80
Ear Height	81.35	123.14	41.79	0.13	1.71
No of Cobs/Row	7.45	8.34	0.89	0.31	0.96
Fresh Ear Weight/Row	0.23	0.25	0.02	0.49	0.25
Grain Moisture/Row	9.17	16.50	7.33	0.13	0.70
Kernel Rows/Cobs	1.30	1.94	0.63	0.09	0.10
Cob Length	5.72	6.06	0.34	0.16	0.41
100 Kernel Weight	21.13	22.99	1.86	0.14	0.71
Grain Yield	25.12	25.98	1.45	1.21	0.99

δ^2_G = Genotypic Variance, δ^2_P = Phenotypic Variance, δ^2_E = Error Variance, GCV % = Genotypic Co-efficient of Variance, PCV % = Phenotypic Co-efficient of Variance.

Tab. 3 Mean squares values for agronomic characteristics, of half-sib families from maize variety Azam.

Parameter	Reps	Treatments	Blocks
Tasseling	5.635	2.709**	0.635
Silking	41.145	5.198**	9.470
Anthesis	120.125	$3.222^{N.S}$	4.795
ASI	20.207	2.964**	3.948
Plant height(cm)	10175.734	276.727**	649.210
Ear height(cm)	913.873	123.140**	296.890
Kernel rows	0.130	1.935**	1.735
Cob length (cm)	15.844	6.059**	0.607
100-kernal wt.	0.125	22.992**	3.257
Grain yield (Kgha^{-1})	4671532.778	2789345.672**	2945605.393

N.S = non-significant
** = Significant at 1% level of significance

Kernels rows per cob

Analysis of variance for kernel rows cob revealed highly significant differences among half-sib families, with the genotypic coefficient of variance noted as 0.09 % (Tab. 2). Minimum average kernel rows per cob were observed as 11 for HSF-157, while maximum average values were 16.84 for HSF-83, with a grand mean of 13.35 among 196 half-sib families (Tab. 1). These results are similar to those reported by Gnanasekaran *et al.* (2008), who observed highly significant differences among the genotypes for kernel rows per cob.

Cob Length

Data recorded for cob length also showed highly significant differences among the half-sib families. The genotypic coefficient of variance was 0.16 % (Tab. 2). The cob length of half-sib families ranged from 9.34 cm to 19.17 cm for HSF-15 and HSF-41, respectively, having a grand mean of 14.81 (Tab. 1). The results are in contrast to those observed by Carlon and Russel (1989), who observed significant differences ($P<0.05$) for cob length in the testcross evaluation of maize synthetic 'BSSS' lines.

Weight of 100 Kernels

Analysis of variance revealed highly significant differences ($P<0.01$) among the half-sib families with a 5.98% coefficient of variation (Tab. 3). Mean values for the weight of 100 kernels ranged from 20 for HSF-140 to 41 for HSF-153. The grand mean was recorded as 32.27 (Tab. 1). These results are similar to those of Rahman et al. (2007), who also reported significant differences ($P<0.05$) for this trait while comparing original and selected maize populations for grain yield.

Tab. 4 Genetic Parameters for the agronomic traits in Half-Sib Families of maize.

Parameters	h^2_{BS}	GA	GG
Days To Tasseling	† 0.87	2.95	5.26
Days To Silking	† 0.66	3.10	5.15
Days To Anthesis	‡ 0.57	2.11	3.67
Anthesis Silking Interval (ASI)	† 0.62	2.20	84.63
No of Plants/Row	† 0.61	4.21	38.25
Plant Height	† 0.66	22.77	14.77
Ear Height	† 0.66	15.10	20.98
No of Cobs/Row	† 0.89	5.32	61.32
Fresh Ear Weight/Row	† 0.94	0.96	97.19
Grain Moisture/Row	‡ 0.56	4.65	19.85
Kernal Rows/ Cob	† 0.67	1.93	14.44
Cob Length	† 0.94	4.79	32.33
100 Kernal Weight	† 0.92	16.08	28.14
Grain Yield	† 0.85	20.23	26.25

†= High Heritability
‡= Moderate Heritability
h^2_{BS} = Heritability (broad scence), GA= Genetic Advance, GG= Genetic Gain

Variance Analysis

The variance analysis results for the investigated traits are shown in Table 2. The grain quantity characteristics and the grain yield of 196 half-sib families of maize were studied. To find the extent of yield variation components that are responsible for the yield differences, it must be kept in mind that total variability is contingent upon non-heritable and heritable components. The coefficient of variation measures the extent of variation present in the population, genetic advances and heritability, as these are prime important steps of the breeding program because this gives information required in the efficient breeding program. The genotypic variance (δ^2_G), phenotypic variance (δ^2_P), error variance (δ^2_E), genotypic coefficient of variance (GCV %), and phenotypic coefficient of variance (PCV %) expressed as a percentage for 14 parameters are presented in Table 2. The phenotypic coefficient of variance (PCV%) was higher than the genotypic coefficient of variance (GCV%) for all traits except for fresh ear weight, where the genotypic co-efficient of variance was greater, which reflect the environmental influence on the trait's expression (Tab. 2).

Heritability

Heritability (h^2) of a trait is vital to find out its response to selection. The genetic improvement for quantitative characters of plants requires reliable estimates of heritability for the plan of efficient breeding. A high heritability of 0.87 was observed for days to tasseling, and for days to mid-silking high heritability of 0.66 was observed, which specifies the low effect of the environment with a relative improvement of the trait (Tab. 4). A moderate heritability estimate of 0.57 was recognized for days to anthesis, which reflects considerable environmental effects on anthesis. For anthesis silking interval (ASI), high heritability estimates of 0.62 were observed. For a number of plants and plant height, high heritability estimates of 0.61 and 0.66 were observed. Mahmood and Hubbard (2004) recognized a high heritability estimate of 0.99 for plant height that shows our results are the same as his results. A high heritability estimate of 0.67 was observed for kernel rows per cob. Mahmood and Hubbard (2004) also observed a high heritability estimate of 0.87 for this parameter. For cob length and 100-kernel weight, a high heritability of 0.94 and 0.92 was observed (Tab. 4), which are in agreement for 100-kernel weight, scrutinized by Sujiprihati *et al*. (2007). High heritability estimates of 0.85 were observed for the grain yield parameter, and such high heritability estimates were also observed (Mohamed and Mohamed, 2017).

Tab. 5 Correlations among yield related agronomic traits.

	DT	DS	DA	ASI	PR	PH	EH	CR	FEW	GM	KR	KW	GY
DT		0.98**	1.00**	1.00**	0.96**	0.93**	0.93**	0.97**	0.28**	0.95**	0.99**	0.98**	0.94**
DS			0.99**	0.99**	0.99**	0.98**	0.98**	1.00**	0.09 $^{N.S}$	0.99**	0.94**	1.00**	0.99**
DA				1.00**	0.97**	0.95**	0.95**	0.98**	0.22**	0.97**	0.98**	0.99**	0.96**
ASI					0.97**	0.94**	0.94**	0.97**	0.24**	0.96**	0.98**	0.98**	0.95**
PR						1.00**	1.00**	1.00**	-0.01 $^{N.S}$	1.00**	0.90**	1.00**	1.00**
PH							1.00**	0.99**	-0.09 $^{N.S}$	1.00**	0.86**	0.99**	0.90**
EH								0.99**	-0.09 $^{N.S}$	1.00**	0.86**	0.99**	0.94**
CR									0.02 $^{N.S}$	1.00**	0.91**	1.00**	1.00**
FEW										-0.04 $^{N.S}$	0.42**	0.07 $^{N.S}$	-0.06 $^{N.S}$
GM											0.89**	0.99**	1.00**
KR												0.93**	0.88**
CL													0.99**

DT-Days To Tasseling, DS-Days To Silking, DA-Days To Anthesis, ASI-Anthesis Silking Interval (ASI), PR-No of Plants/Row, PH-Average Plant Height of Five Plants, EH-Average Ear Height of Five Plants, CR-No of Cobs/Row, FEW-Fresh Ear Weight/Row, GM-Grain Moisture/Row, KR-Kernal Rows/ Cob (Average of 3 Cobs), CL-Cob Length (Average Cob Length In 3 Cobs), KW-100 Kernal Weight, GY-Grain Yield

$^{N.S}$ = non-significant, ** = Significant at 1% level of significance

Correlation Analysis

The degree of correlation is important to factor in yield, which is a complex character among different characters. Steel and Torrie (1960) scrutinized that correlation is the intensity of the measures between the traits. The assortment of one trait affects the progress of all characters that are positively correlated. The correlation coefficients among the different traits were studied (Tab. 5), which shows a highly significant and positive correlation between grain yield with all parameters, especially with the number of plants per row and the number of cobs per row. This shows that our results are quite good and true because when the number of plants per row increases, the grain yield will be increasing; this will automatically increase the number of cobs per row, which results in the increment of grain yield. A highly significant and positive correlation was also observed between grain yield and cob length, kernel rows per cob, grain moisture, days to tasseling, silking, and anthesis. However, a non-significant and negative correlation factor was observed between grain yields and fresh ear weight. A non-significant and positive correlation factor was observed between 100-kernel weights with fresh ear weight, and a highly significant and positive correlation was observed with no plant per row (Tab. 5).

Tab. 6 (Part-A) List of half-sib families (HSF) showing grain yield (GY kg ha^{-1}) of two replications.

HSF	GY	HSF	GY	HSF	GY	HSF	GY	HSF	GY	HSF	GY	HSF	GY
HSF-1	**3697**	HSF-15	**2293.5**	HSF-29	**3661.5**	HSF-43	**3670**	HSF-57	**4107.5**	HSF-71	**3026**	HSF-85	**3462**
HSF-2	**2870.5**	HSF-16	**3404**	HSF-30	**3065**	HSF-44	**2803**	HSF-58	**3042.5**	HSF-72	**3895.5**	HSF-86	**3055**
HSF-3	**3131**	HSF-17	**3676.5**	HSF-31	**2046.5**	HSF-45	**4043**	HSF-59	**3970**	HSF-73	**3662**	HSF-87	**4785.5**
HSF-4	**4023**	HSF-18	**3527.5**	HSF-32	**3066**	HSF-46	**3839**	HSF-60	**3785**	HSF-74	**4949**	HSF-88	**3996.5**
HSF-5	**4767**	HSF-19	**4061**	HSF-33	**3734.5**	HSF-47	**3725**	HSF-61	**4578**	HSF-75	**4719.5**	HSF-89	**4527**
HSF-6	**4174**	HSF-20	**3316**	HSF-34	**3428**	HSF-48	**6905.5**	HSF-62	**5180**	HSF-76	**3845**	HSF-90	**5198**
HSF-7	**5333**	HSF-21	**4843.5**	HSF-35	**4169.5**	HSF-49	**4148**	HSF-63	**5755.5**	HSF-77	**5215**	HSF-91	**4475.5**
HSF-8	**4942**	HSF-22	**4695**	HSF-36	**5996**	HSF-50	**4313.5**	HSF-64	**6660**	HSF-78	**5299.5**	HSF-92	**4299.5**
HSF-9	**7225.5**	HSF-23	**3484**	HSF-37	**3178.5**	HSF-51	**4460.5**	HSF-65	**5099.5**	HSF-79	**5115.5**	HSF-93	**3335**
HSF-10	**3980.5**	HSF-24	**4033**	HSF-38	**4409.5**	HSF-52	**5300.5**	HSF-66	**4989.5**	HSF-80	**4017**	HSF-94	**5557**
HSF-11	**4053**	HSF-25	**5387.5**	HSF-39	**4117.5**	HSF-53	**6613**	HSF-67	**5494**	HSF-81	**4345.5**	HSF-95	**4105.5**
HSF-12	**4436.5**	HSF-26	**4752**	HSF-40	**4474**	HSF-54	**4347**	HSF-68	**4354**	HSF-82	**3350.5**	HSF-96	**3430**
HSF-13	**3816**	HSF-27	**6555**	HSF-41	**5373.5**	HSF-55	**5936.5**	HSF-69	**4367**	HSF-83	**6940**	HSF-97	**5593**
HSF-14	**4645.5**	HSF-28	**4601**	HSF-42	**5112.5**	HSF-56	**4711**	HSF-70	**5068**	HSF-84	**8378**	HSF-98	**2437.5**

Tab. 6 (Part-B) List of half-sib families (HSF) showing grain yield (GY kg ha^{-1}) of two replications.

HSF	GY	HSF	GY	HSF	GY	HSF	GY	HSF	GY	HSF	GY	HSF	GY
HSF-99	3060.5	HSF-113	2446.5	HSF-127	6048.5	HSF-141	3447	HSF-155	3817	HSF-169	3658	HSF-183	4193.5
HSF-100	3153	HSF-114	3449.5	HSF-128	3662.5	HSF-142	3208	HSF-156	3589	HSF-170	3288	HSF-184	3490.5
HSF-101	3745	HSF-115	5169.5	HSF-129	3519	HSF-143	3846	HSF-157	4438.5	HSF-171	3915.5	HSF-185	3367.5
HSF-102	4407.5	HSF-116	3791.5	HSF-130	3894	HSF-144	3271.5	HSF-158	4043.5	HSF-172	4131	HSF-186	3551
HSF-103	4907.5	HSF-117	3175	HSF-131	3074	HSF-145	4525.5	HSF-159	3867	HSF-173	3843	HSF-187	4746.5
HSF-104	4224.5	HSF-118	4808	HSF-132	4758.5	HSF-146	4360.5	HSF-160	4442	HSF-174	4850.5	HSF-188	4552
HSF-105	4420	HSF-119	5298	HSF-133	3550.5	HSF-147	3623.5	HSF-161	5200	HSF-175	4365	HSF-189	4151
HSF-106	5409.5	HSF-120	2385	HSF-134	4551.5	HSF-148	3217	HSF-162	3631.5	HSF-176	5285.5	HSF-190	5560
HSF-107	4460	HSF-121	3013.5	HSF-135	4561	HSF-149	4634.5	HSF-163	5735.5	HSF-177	5424.5	HSF-191	4197.5
HSF-108	2427	HSF-122	3296	HSF-136	3677	HSF-150	5099.5	HSF-164	5931	HSF-178	3455	HSF-192	4141
HSF-109	5024.5	HSF-123	3657.5	HSF-137	3137	HSF-151	3850.5	HSF-165	5268	HSF-179	7376.5	HSF-193	4157.5
HSF-110	3684	HSF-124	3330	HSF-138	3226	HSF-152	4686.5	HSF-166	8257.5	HSF-180	10710	HSF-194	8283.5
HSF-111	3687	HSF-125	4326	HSF-139	5262.5	HSF-153	3661.5	HSF-167	4841.5	HSF-181	4268.5	HSF-195	5782.5
HSF-112	5700.5	HSF-126	3919	HSF-140	4804	HSF-154	3239.5	HSF-168	6138.5	HSF-182	4752	HSF-196	2729.5

Grain yield (kg ha^{-1})

Grain yield improvement is one of the major aims of every plant breeding program. Several methods of selection have been used by maize breeders to improve yield per unit area and develop high- yielding genotypes. Among them, the four major types are mass selection, selection based on half-sib progeny performance, full-sib performance, and selfed progeny selection (Okoye et al., 2018). Statistical analysis of the data regarding grain yield revealed highly significant genetic variation (P<0.01) among the half-sib families. The genetic coefficient of variance (CV) for grain yield was 15.62 % (Tab. 3). Grain yield of half-sib families ranged from 2046.50 kg ha^{-1} for HSF-31 to 10710.50 kg ha^{-1} for HSF-180. The grand mean calculated was 4367.54 kg ha^{-1} (Tab. 1). Our results are consistent with those of Tanner and Smith (1987), who conducted eight cycles of half-sib family (BSK$_{(S)}$) recurrent selection in the Krug yellow dent maize population, in which they obtained significant variances among test crosses for grain yield.

Conclusion

The phenotypic coefficient of variance was higher than the genotypic coefficient of variance for all traits except for fresh ear weight which reflects the environmental influence on the expression of the trait. High to moderate heritability was observed for days to tasseling, days to mid silking, days to anthesis, anthesis- silking interval, kernel rows per cob, cob length, and grain yield. Highly significant and positive correlations were observed between grain yield and cob length (0.99), kernel rows per cob (0.88), grain moisture (1.00), days to tasseling (0.94), silking (0.99), and anthesis (0.96). The negative and non-significant correlations were observed between grain yield and fresh ear weight (-0.06). Maximum grain yields of 10710 kg ha^{-1} was recorded for HSF-180 while the minimum 2046 kg ha^{-1} was obtained by HSF-31

Acknoledgement:

The authors are also thankful to the Cereal Crop Research Institute (CCRI) Pakistan for providing germplasm and technical support.

Authors contributions:

Nasr Ullah Khan and Muhammad Saad Ahmed conceived the idea and designed the project. Muhammad Ishfaq Khan, Rida Nisar, Muhammad Muddasir, and Muhammad Umer Mustafa conducted the experiment and collected the data. Muhammad Arshad, Rehan Naeem, Mohsin Khurshid, and Muhammad Khuram Razzaq analyzed the data. Nasr Ullah Khan, Muhammad Saad Ahmed, Muhammad Ishfaq Khan, and Abdul Majid drafted the manuscript. All authors read the manuscript before submission.

Conflict of interests:

None

References

Coors, J. (1988). Response to four cycles of combined half-sib and S1 family selection in maize. *Crop science*, 28**,** 891-896.

Evenson, R. E., Gollin, D. (2003). Assessing the impact of the green revolution, 1960 to 2000. *Science*, *300***,** 758-62.

Gnanasekaran, M., Jebaraj, S., Muthuramu, S. (2008). Correlation and path co-efficient analysis in sesame (Sesamum indicum L.). P*lant archives*, *8***,** 167-169.

Hallauer, A. L. (2012). Recurrent selection methods to improve germplasm in maize. *Maydica*, *57***,** 266-283.

Hallauer, A. R., Carena, M. J., Miranda Filho, J. d. (2010). Quantitative genetics in maize breeding. Springer Science & Business Media.

Hidayat, U., Khalil, I., Ghulam, H., Iltaf, U. (2006). Performance of local and exotic inbred lines of maize under agro-ecological conditions of Peshawar. *Sarhad Journal of Agriculture*, *22*, 409-414.

Keeratinijakal, V., Lamkey, K. R. (1993). Responses to reciprocal recurrent selection in BSSS and BSCB1 maize populations. *Crop Science*, *33*, 73-77.

Mahmood, R., Hubbard, K. G. (2004). An analysis of simulated long-term soil moisture data for three land uses under contrasting hydroclimatic conditions in the Northern Great Plains. *Journal of Hydrometeorology*, *5*, 160-179.

Mohamed, H., Mohamed, M. (2017). - Estimation of Some Genetic Parameters, Correlation and Heritability in Various Maize Traits. - 5.

Okoye, N., Oluwaranti, A., Fakorede, M., Akinwale, R. (2018). Seed Production, Growth and Grain Yield of Self, Half-sib and Bulk-sib Progenies Developed from an Early-maturing Maize (*Zea mays L.*) Population. *Asian Research Journal of Agriculture*, 1-12.

Pixley, K. V., Dhliwayo, T., Tongoona, P. (2006). Improvement of a maize population by full-sib selection alone versus full-sib with selection during inbreeding. *Crop science*, *46*, 1130-1136.

Rahman, H., Arifuddin, Z., Shah, S., Iqbal, M., Khalil, I. (2010). Evaluation of maize S2 lines in testcross combinations I: flowering and morphological traits. *Pak. J. Bot. 42*, 1619-1627.

Rahman, H., Khalil, I., Islam, N., Rafi, A. (2007). Comparison of original and selected Maize populations for grain yield traits. *Sarhad Journal of Agriculture* (Pakistan).

STAT, F., 2012. FAOSTAT-Statistical Database, (2012).

Steel, R. G. D., Torrie, J. H., (1960). Principles and procedures of statistics. Principles and procedures of statistics.

Stromberg, L., Compton, W. (1989). Ten cycles of full-sib selection in maize. *Crop science*, *29*, 1170-1172.

Sujiprihati, S., Yunianti, R., Syukur, M. (2007). Pendugaan nilai heterosis dan daya gabung beberapa komponen hasil pada persilangan dialel penuh enam genotipe cabai (*Capsicum annuum L.*). *Journal Agronomi Indonesia* (*Indonesian Journal of Agronomy*). *35*.

Tanner, A. and Smith, O. (1987). Comparison of Half-Sib and S1 Recurrent Selection in the Krug Yellow Dent Maize Populations 1. *Crop science*, *27*, 509-513.

Tariq, M. and Iqbal, H. (2010). Maize in Pakistan-an overview. *Kasetsart J.*(*Nat. Sci.*), *44*, 757.

Vales, M., Malvar, R., Revilla, P. and Ordas, A. (2001). Recurrent selection for grain yield in two Spanish maize synthetic populations. *Crop science*, *41*, 15-19.

Zhou, Y., Han, Y., Li, Z., Fu, Y., Fu, Z., Xu, S., Li, J., Yan, J. and Yang, X. (2012). ZmcrtRB3 Encodes a Carotenoid Hydroxylase that Affects the Accumulation of α-carotene in Maize Kernel F. *Journal of integrative plant biology*, *54*, 260-269.